ISSN 0704-3716

Canadian Translation of Fisheries and Aquatic Sciences

No. 5358

The possibility of using the Arctic char for commercial farming in the Barents Sea

A. G. Chernitskii, G. G. Matishov and V. V. Ermolaev

Original title: Vozmozhnost' ispol'zovaniya arkticheskogo gol'tsa dlya tovarnogo lososevodstva v Barentsevom more

In: Polyarnaya marikul'tura: 3-37, 1987
Polar Sea Farming: 3-37, 1987

Published by: Kola Branch of the USSR Academy of Sciences

Original language: Russian

Available from:
Canada Institute for Scientific and Technical Information
National Research Council
Ottawa, Ontario, Canada K1A 0S2

1988

51 typescript pages

90-01490/ /

Secretary of State / Secrétariat d'État

MULTILINGUAL SERVICES DIVISION – DIVISION DES SERVICES MULTILINGUES

TRANSLATION BUREAU / BUREAU DES TRADUCTIONS

LIBRARY IDENTIFICATION – FICHE SIGNALÉTIQUE

Translated from - Traduction de	Into - En
RUSSIAN	ENGLISH

Author - Auteur

A.G. Chernitskii et al.

Title in English or French - Titre anglais ou français

THE POSSIBILITY OF USING THE ARCTIC CHAR FOR COMMERCIAL FARMING IN THE BARENTS SEA

Title in foreign language (Transliterate foreign characters)
Titre en langue étrangère (Transcrire en caractères romains)

VOZMOZHNOST' ISPOL'ZOVANIYA ARKTICHESKOGO GOL'TSA DLYA TOVARNOGO LOSOSEVODSTVA V BARENTSEVOM MORE

Reference in foreign language (Name of book or publication) in full, transliterate foreign characters.
Référence en langue étrangère (Nom du livre ou publication), au complet, transcrire en caractères romains.

Polyarnaya marikul'tura

Reference in English or French - Référence en anglais ou français

Polar Sea Farming

Publisher - Editeur	DATE OF PUBLICATION / DATE DE PUBLICATION			Page Numbers in original / Numéros des pages dans l'original
Kola Branch of the USSR Academy of Sciences	Year / Année	Volume	Issue No. / Numéro	pp 3 - 37
Place of Publication / Lieu de publication				Number of typed pages / Nombre de pages dactylographiées
Apatity, USSR	1987	-	-	49

Requesting Department / Ministère-Client: DFO

Translation Bureau No. / Notre dossier nº: 3287261

Branch or Division / Direction ou Division: IPB

Translation (Initials) / Traducteur (Initiales): GAD

Person requesting / Demandé par: Audrey Conroy, St. John's NFLD.

Your Number / Votre dossier nº:

Date of Request / Date de la demande: November 12th, 1987.

UNEDITED TRANSLATION
For information only
TRADUCTION NON REVISÉE
Information seulement

Canada

SEC 5-111 (Rev. 82/11)

Secretary of State | Secrétariat d'État

MULTILINGUAL SERVICES DIVISION – DIVISION DES SERVICES MULTILINGUES

TRANSLATION BUREAU | BUREAU DES TRADUCTIONS

Client's No.–N° du client	Department – Ministère	Division/Branch – Division/Direction	City – Ville
	DFO	IPB	St. John's NFLD
Bureau No.–N° du bureau	Language – Langue	Translator (Initials) – Traducteur (Initiales)	
3287261	Russian	GAD	JAN 2 5 1988

Polar Sea Farming, Kola Branch of the Murmansk Marine Biology Institute, N.F.Nefelova (Ed.), Apatity, USSR, 1987, pp 3-37.

UDC 597.553.2

THE POSSIBILITY OF USING THE ARCTIC CHAR FOR COMMERCIAL FARMING IN THE BARENTS SEA (Operational information)

By Candidate in Biological Sciences A.G. Chernitskii, Doctorsin Geographical Sciences G.G. Matishov and V.V. Ermolaev, Candidate in Biological Sciences A.F. Fedorov (Ed.)

A survey of published data and findings accumulated at the Murmansk Marine Biology Institute on the biology of the arctic char and the biotechnology of its breeding is presented. Gaps in our knowledge of the biology of this species are shown and directions are offered for the studies needed forthe biotechnological mastery of the migratory char in polar sea farming.

This operational information will be of interest to ichthyologists, ecologists and fisheries specialists.

CONTENTS

		Page (ori
1.	The grounds for choosing the arctic char as an object of polar sea farming	3
2.	General description of the species	5
3.	The char of the Kola Peninsula	19
4.	The char of the Novaya Zemlya Is.	23
5.	Breeding of char in aquaculture	28
6.	Directions for immediate studies in the biology of the arctic char and prospects for its utilization in polar sea farming	33
	REFERENCES	35

1. The grounds for choosing the arctic char as an object of polar sea farming /3*

Three species of migratory salmon inhabit the Barents Sea: the Atlantic salmon - Salmo salar L., the sea trout - S. trutta L., and the arctic

*The numbers in the right-hand margin indicate the corresponding pages in the original. - Transl.

Canada

UNEDITED TRANSLATION
For information only
TRADUCTION NON REVISEE
Information seulement

SEC 5-25 (Rev. 82/11)

char - Salvelinus alpinus L. Their commercial importance differs: the Atlantic salmon is a prime fisheries target, while the sea trout and the arctic char are of secondary importance. The differences are due not so much to fish quality, as to their abundance. Catches of Atlantic salmon in large rivers reached tens of tonnes per year, while the sea trout and arctic char were only an incidental catch in the Atlantic salmon fishery. Fish-culture was also concentrated on the Atlantic salmon. The aim of this work, which has a 50-year history in the Barents sea basin, was pasture fish management, that is, the growing of fry at fish culture plants to replenish natural populations, primarily those whose abundance had been undermined by overfishing or by dam construction on rivers. The selection of the Atlantic salmon is justified by the fact that it dominated in the fishery and had the highest-priority need for measures to preserve its abundance.

At present, sea farming work has been begun on the Barents coast. This variant of fish culture involves complete control over the life cycle of the fish. The approach to the selection of an object for commercial breeding must also accordingly be different than in pasture fish culture. It is not the abundance of the species and its commercial significance that are in the forefront in commercial breeding, but its ability to adapt to breeding conditions, biological technology, and the possibility of influencing its rate and direction of development.

The coastal regions of the Barents sea are not a typical habitat for the Atlantic salmon, since the fry grow in the river and then migrate to the Atlantic, and the Barents sea serves only as a transit body of water for this species. The arctic char migrates for foraging from rivers precisely to the

Barents sea, which is a trophic body of water for it. Ponds for cultivation of the salmon will thus be located in water areas where feeding migrations of the arctic char take place, but not those of the Atlantic salmon.

All salmon are characterized by a high ecological plasticity, although the artic char considerably surpasses the Atlantic salmon in its capacity for morphogenesis. It is more variable than the Atlantic salmon and in various ecological conditions forms a large number of subspecies and ecotypes /4 that are better adapted to particular conditions. The arctic char will probably be more promising for breeding, especially since many forms of char live in the USSR, which creates better possibilities for selection work than in other countries.

The arctic char is characterized by the important peculiarity of forming single populations of freshwater and migratory individuals, so that small freshwater fish can be used as brood stock, obtaining from them fry for sea farming. The maintenance of such brood stocks is cheaper than that of large migratory spawners. Only the latter is so far possible for the Atlantic salmon.

The arctic char is in addition the most cold-resistant salmon, which is very important for polar sea farming. In the Barents sea, we have the Novaya Zemlya char, a unique form which is the most northern of the accessible forms and the largest. The arctic char is also attractive because of the fact that on the basis of the fragmentary data available in the literature, the migration of its juveniles from the river to the sea is not so strictly determined and may not be accompanied by the whole complex of "smoltification" changes that are characteristic of the Atlantic salmon. This will make it possible to make effective use of accelerated development of the juvenile fish by changing abiotic environmental factors and to transfer it to sea water at a time suitable for the fish culturists.

Change in the nature of fish culture thus leads to a change in the requirements made of the breeding objects. In conditions of the Barents sea, therefore, the Atlantic salmon as before keeps its importance as an object of the fishery and pasture fish culture, while the artic char may appear to be more adequate in terms of biological indicators as an object for sea farming.

In this work we have attempted to generalize the available published data on the biology and biotechnology of this species, to show the gaps in our knowledge of the life of this most puzzling and little-studied of all the salmon, and to mark out priority tasks in further research.

Soviet and foreign publications, as well as the preliminary results obtained by the expedition of the Murmansk Marine Biology Institute of the Kola Branch of the USSR Academy of Sciences to the Novaya Zemlya Is., in August-September, 1986, on the "Pomor" scientific-research vessel, were the information sources used.

/5

2. General description of the species

Systematic position and diagnosis. The arctic char Salvelinus alpinus L. (Fig. 1)

order Clupeiformes

suborder Salmonoidei

family Salmonidea

genus Salvelinus

L.S. Berg (1948) gives the following characteristics of this species: L III-IV 8-11, A III-IV 7-9, 1.1.130-140, squ. $190\frac{36-37}{38}240$, 18-30 gill rakers on first arch, 10-12 branchiostegal rays, 30-44 pyloric caecae (in Kara R.). There are 26-37 scales in one tenth part of the Schmidt's body length in front of D. In juveniles, the upper jaw does not go beyond the perpendicular

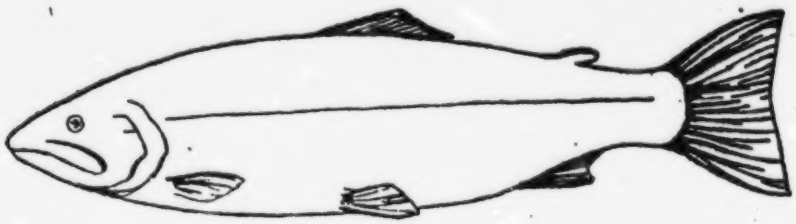

Fig. 1. Arctic char Salvelinus alpinus L. (migratory form).

of the posterior margin of the eye; it does reach in old fish, but not so far as in S. malma. The dorsum has a bluish-steely tint; there are no dark spots on either the fins or the body; small red or orange spots appear on the back during spawning. Length 35-65 cm, weight 1-3 kg, maximal length up to 88 cm and weight up to 10-15 kg.

However, the artic char is very variable. The appearance, biological features and other characters vary greatly both in fishes living in different bodies of water and in fishes inhabiting the same body of water. Even the color of the meat can vary in fishes of different populations or in fishes of the same population in different years (Table 1, 2).

Geographic distribution, structure of populations. The Arctic coast /6 is the center of distribution of the arctic char. The arctic char populations also occupy the eastern part of North America, Northern and Central Europe. Some isolated populations are found in the southern part of Alaska (Fig. 2).

The arctic char is the best adapted of all the salmon to the severe conditions of the Arctic basin. The arctic char reaches its maximal size and its populations reach their maximal density in places where there are no fresh-water fishes at all.

TABLE 1

Distribution by meat color of fishes from the rivers of Northern Labrador, % (Andrews, Lear, 1956).

Место отлова 1	Цвет мяса 2		
	белый 3	розовый 4	красный 5
Эдлэток 6	9	84	7
Найн 7	7	43	50
зал. Окак 8	23	49	29
Хеврон 9	0	56	44
Рамах 10	0	64	36

Key: 1 - place caught; 2 - color of meat; 3 - white; 4 - rose; 5 - red; 6 - Adlatok; 7 - Nain; 8 - Okak Bay; 9 - Hebron; 10 - Ramakh*.

TABLE 2

Distribution by flesh color of arctic char caught in Bay in different years, % (Andrews, Lear, 1956, with alterations).

Год вылова 1	Цвет мяса 2		
	белый 3	розовый 4	красный 5
Катадромные мигранты 6			
1944	8	27	65
1945	23	28	49
1946	31	25	44
1947	15	26	59
1948	18	29	53
1949	27	55	18
Анадромные мигранты 7			
1948	16	30	54

Key: 1 - year caught; 2 - flesh color; 3 - white; 4 - rose; 5 - red; 6 - catadromous migrants; 7 - anadromous migrants.

The extreme variability of forms is one of the basic characteristics of the arctic char. Within its range, the arctic char is represented by various groups and populations adapted to specific environmental conditions. This has

*Here and subsequently, denotes a place name for which either approximate or transliterated spelling is given. - Transl.

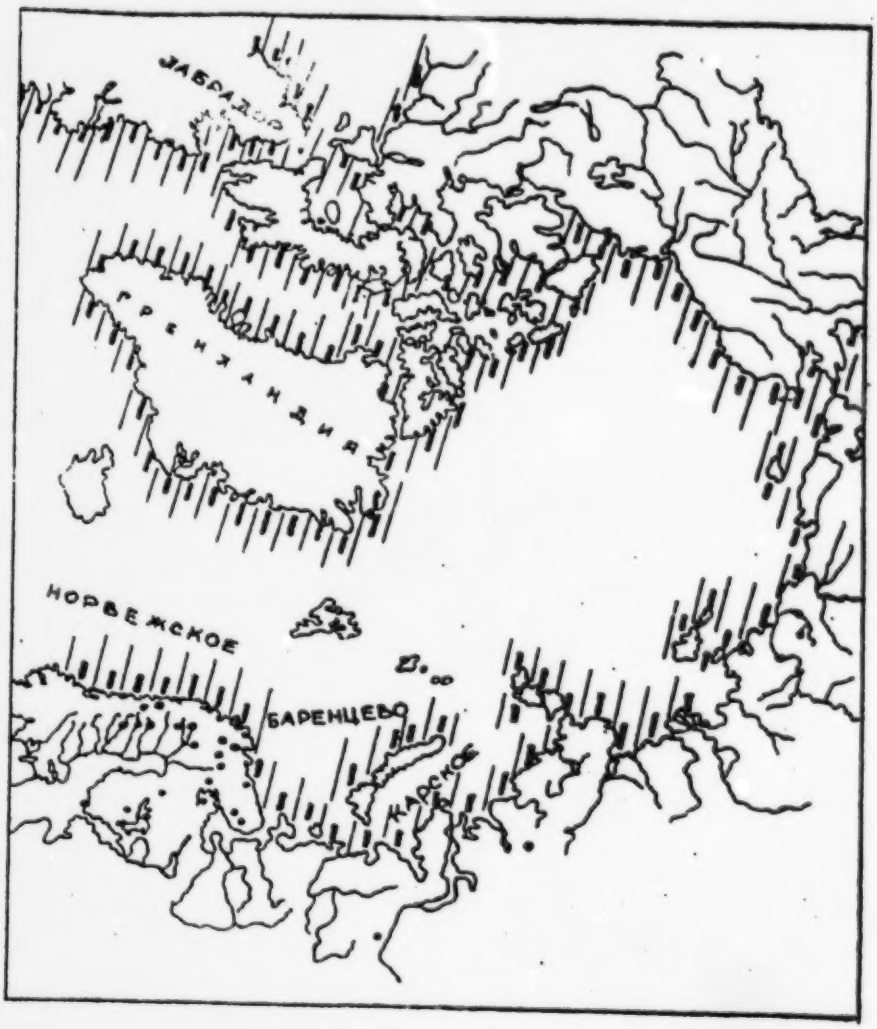

Fig. 2. Range of the arctic char (Johnson, 1960, with additions).

had the result that in the last century, 13 species of arctic char were described in the British Isles and 6 species were distinguished in Sweden. The arctic char from the bodies of water of the Taimyr peninsula have been described as an independent species. But it was later established that all these form have intraspecies status and were formed as the result of the influence of various conditions in which the fish exist, and possibly by the different food objects used by them. In addition, the forms that had been distinguished at the species level turned out to be relict populations of the arctic char.

At present, lake, lake-river and migratory forms are distinguished within the range of the arctic char. In many bodies of water, each of these is further subdivided into various groups. A great diversity of forms is observed in the lake char of the Alps: the typical, predaceous deep-water, dwarf littoral that feeds on invertebrates, and the deep-water dwarf form. They are clearly separated in some bodies of water, while in others they form /8 single populations. The relationships between the freshwater and migratory forms of the arctic chars living in the basin of the sameriver may also be different - from isolation to combination in a single population (Savvaitova, Tsarev, 1986). Migratory arctic char populations are divided by time of maturation and spawning migration and these groupings also often differ in size and rate of growth of individuals. Some authors distinguish arctic char groups that spawn in the spring in lakes and in the fall in rivers (Johnson, 1980).

Life cycle. The migratory arctic char passes a large part of its life under ice, and it is therefore that part of its life cycle that is confined to the relatively short period of open water that has mainly been investigated by biologists. As in all migratory salmon, the life cycle of the arctic char consists of an alternation of freshwater and marine periods.

TABLE 3

Characteristics of migratory arctic char populations (Johnson, 1980; Dempson, Green, 1985).

Место поимки	Возраст 1-й миграции в море, лет	Величина при миграции, мм	Анадромные мигранты: длина, мм		возраст, лет		Возраст первого созревания, лет	Величина созревших рыб, мм	Плодовитость	
			средняя	пределы	средний	пределы			абсолютная	относительная на 100 г
1	2	3	4	5	6	7	8	9	10	11
р.С.Чарльз Лабрадор 52°N 55°W 12a	2-5	-	450	251-708	6.2	4-9	-	-	-	-
р.Сенд-Хилл Лабрадор 53°N 56°W 13a	-	-	400	187-641	5.2	2-10	-	-	-	-
руч.Миддл-Дабл Лабрадор 54°N 58°W 14	-	-	419	196-767	5.3	2-10	-	-	-	-
р.Фрейзер Лабрадор 56°N 63°W 15	3-7	87-191	451	127-820	8.3	3-18	5(6.9)	262(381)	4685	249
фиорд Нагвак Лабрадор 59°N 63°W 16	2-6	78-115	-	-	-	-	7(10.0)	358	2876	281
р.Лиф зал.Унгава 58°N 70°W 17	3-7	220	-	-	-	-	6(8.0)	(500)	4397	167
р.Сильвия Гриннелл зал.Фробишер 63°N 68°W 18	4-7	130-170	476	130-825	-	4-21	11	450	3465	179
прол.Камберленд Баффинова Земля 66°N 93°W 19	5-7	114-210	562	250-750	17.2	7-20	11	392	5400	284

Key: 1 - place caught; 2 - age of 1st migration to sea, years; 3 - size at migration, mm; 4 - anadromous migrants; 5 - length, mm; 6 - average; 7 - limit; 8 - age, years; 9 - age of first maturity, years; 10 - size of mature fish, mm; 11 - fecundity; 12 - absolute; 13 - relative per 100 g; 12a - S.Charles R., Labrador, 52°N 55°W; 13a - Sand Hill, Labrador, 53° 56°W; 14 -Middle Double stream, Labrador, 54°58°W; 15 - Fraser R., Labrador, 56°63°W; 16 - Nagvak* fjord, Labrador, 59°N 63° W; 17 -Leaf R., Ungava Bay, 58° 70°W; 18 - Sylvia Grinnell R., Frobisher Bay, 63°N 68°W; 19 - Cumberland str., Baffin I., 66°N 93°W.

TABLE 3 (Cont'd)

I	2	3	4	5	6	7	8	97	I0	II
р.Сэнди Поинт зал.Хадсон 6I°N 93°W 1	-	-	6I3	248-928	7.7	3-I7	-	-	-	-
р.Диана зал.Хадсон 62°N 92°W 2	-	-	567	I76-882	8.4	3-20	-	-	-	-
р.Джейко о-в Виктория 69°N I03°W 3	-	-	424	209-822	9.5	3-22	-	-	-	-
оз.Нейвик п-ов Кент 68°N I07°W 4	4-7	I32	598	I20-900	-	5-2I	I0	620	478I	I40
р.Сагаванирктон Аляска 70°N I48°W 5	2-5	I45-I95	482	2I0-7I0	-	-	6-7	48I	4I53	335
зал.Кресвел о-в Сомерсет 6	-	-	-	-	-	-	I9(I3-25)	383-570	I465-I7II	I53-I70
зал.Мейкинсон о-в Элесмир 7	-	-	-	-	-	-	I2-I6	450	I600	I58-20I
р.Фирс Юкон 8	3	-	-	-	-	-	4-I5	530	4954	369
р.Яма и Яна Охотское море 9	2-3	-	-	-	-	-	4-II	300-450	3I80	378

Key: 1 - Sandy Point R.; Hudson Bay, 61°N 93°W; 2 - Diana R., Hudson Bay, 62°N 92°W; 3 - Jako* R., Victoria I., 69° 103°W; 4 - Neivik*L., Kent Peninsula, 68°N 107°W; 5 - Sagavanirktok R., Alaska 70°N 148°W; 6 -Creswell Bay, Somerset I.; 7 - Meikinson* Bay, Ellesmere I.; 8 - Fierce*R., Yukon; 9 - Yama and Yana rivers, Sea of Okhotsk.

/8

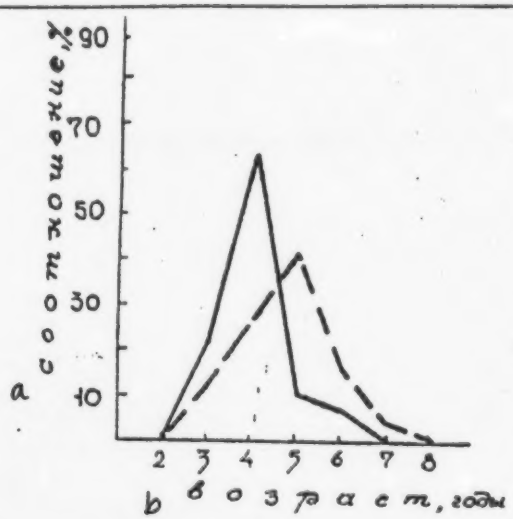

Fig. 3. Age makeup of arctic char smolts from Nain Bay (from tabular data of Dempson, Green, 1985).
a - percentage; b - age, years.

/11

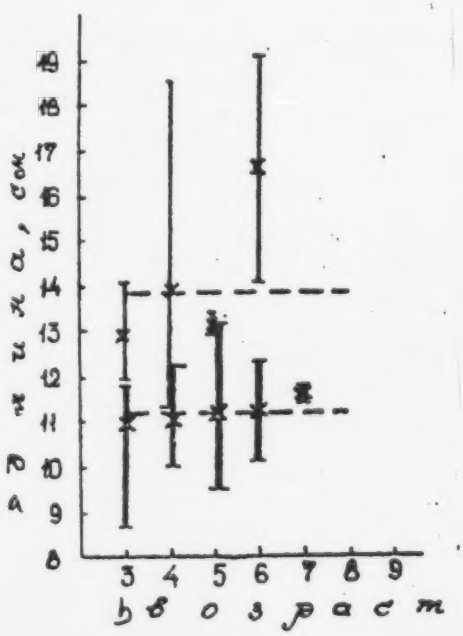

Fig. 4. Length of smolts of different age that migrated in 1979 (top) and 1980 (bottom). Dashed line - mean value for each year (from tabular data of Dempson, Green, 1985).
a - length, cm; b - age.

The young of the migratory arctic char spends the first several /8 years of its life, from 1 to 9 years in fresh water. As soon as the arctic char becomes a smolt, it begins its migrations to the sea. The age of smoltification is different in different populations (Table 3). In the artic char, smoltification is less pronounced than in other migratory salmon. The results of the study of the arctic char of Labrador showed that the age of smolts can vary in a wide range (Fig. 3), but the size of the fish of different age is rather similar (Fig. 4). Apparently, as also in the Atlantic salmon, the first migration to the sea is associated not with a definite age, but with the achievement of a certain physiological condition. The fact that both the age of smolts as well as their length differed in the two succeeding years is interesting (Fig. 3,4).

The downstream migration begins while still under ice. The larger individuals are the first to migrate to sea. Having arrived in sea water, the char spreads out to its fattening places. The distance which the char travels has not been finally determined. Some populations do not go far out to sea, but find feeding places on the coast. Very little is known about long migrations /11 of the char at sea. Migrations along the coast are the most frequent. The longest known path traveled by the char is 940 km into the Tuloma R. in Murmansk oblast. This char had previously been tagged in the Vardness R. in Northern Norway (Jensen, Berg, 1977). While at sea, the char keeps in small schools consisting of fish of a certain size.. Mixing of different age and length groups at sea is not observed (Moore, 1975). The migrations of the char upstream for wintering and spawning begin in the second half of July. The density of populations migrating for spawning can be rather considerable - up to 700 specimens per day. The peak of migrations occurs in August - September.

The fish that migrate from the sea to freshwater include both those which will spawn in the current year as well as sexually immature fish. Some of the sexually immature fish return to sea after wintering in the lake, while some, as has been described for the char of the Canadian Arctic (Johnson, 1980), ascend in the spring floods to the next lake where they spawn in the fall. The spawning migration thus continues for two years and takes place in two stages, since the lower lake is not suitable for spawning, while the channel between the wintering and spawning lakes is shallow and the char can only traverse it in the spring floods. It has been established that some of the fish, having arrived at the upper lake, spend two years there, but it has not been determined whether spawning takes place in the first or the second year. The migratory char may thus pass up to three years in freshwater.

The char goes up river in the fall at a water temperature of 8-12° in /12 August, and 5° in September (Dempson, Green, 1985). Spawning of migratory char does not occur annually, as arule, but once in every two-three years. But a population of migratory char with annual spawning does live in the Norwegian Salangen R. (Norden, 1961). There are usally more females than males among the migrants - 55-75% (Dempson, Green, 1985). According to some data, the char wintering in lakes is inactive, according to others, very active (Johnson, 1980). In the spring, when meltwater fills all the streams and brooks, the char that has overwintered and spawned in the fall of the preceding year, descends to the sea for fattening.

Age and growth. Growth of the char begins immediately after hatching, while still in the mixed feeding stage. The fry begin to feed at a body length of 20-23 mm. The char's rate of grow varies greatly in different populations, but

/13

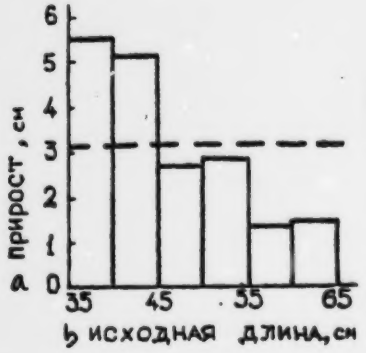

Fig. 5. The influence of the initial length of the char on the increment during the marine fattening (based on tabular data of Dempson, Green, 1985). Dashed line - average value for the entire group.

a - increment, cm; b - initial length, cm.

TABLE 4

Age make-up of migratory char migrating into the rivers of Northern Labrador, % (Andrews, Lear, 1956, with alterations).

Место отлова 1	Возраст, гг. 2												Средний возраст 3
	5+	6+	7+	8+	9+	I0+	II+	I2+	I3+	I4+	I5+	I6+	
Эдлэток 4	I	7	27	23	I0	I9	8	2	2	0	0	0	8.5±0.2
Найн 5	0	3	I6	2I	28	I7	8	6	I	0	0	0	8.9±0.I
зал. Оккак 6	0	0	3	I3	26	20	2I	8	8	0	0	I	I0.2±0.2
Хопрон 7	0	0	I	9	27	23	II	9	I6	4	0	0	I0.5±0.2
Рамах 8	0	0	4	I3	I5	22	I5	I8	5	2	5	I	I0.5±0.2

Key: 1 - place caught; 2 - age, years; 3 - average age; 4 - Adlatok
5 - Nain; 6 - Okak Bay; 7 - Hebron; 8 - Ramakh*.

on the whole the growth of the arctic char is relatively low in the first two years of the freshwater period. The length increases by an average of 2.5 cm a year. The first annulus on the scale often does not form on the char juveniles from the northern regions of Norway, due to the very small increment in body length (Gullestad, 1976). The rate of growth intensifies to 3.5 cm per year in the next two years.

The char feeds actively and grows while at sea. Results of tagging of the char in the Fraser R. (Labrador, Canada) have shown that the increment while at sea is higher in smaller and apparently younger fishes (Fig. 5). No significant differences have been found in the growth of char by sex.

The rate of growth of the char in different regions of the Arctic basin of America is shown in Fig. 6. The maxiaml age of the fishes in different populations of the western, central and eastern forms is 18-20 years (Dempson, Green, 1985). But many migratory char specimens are also known that have lived to a considerable age - 33 years (Johnson, 1980). Char living even in adjacent rivers may differ in both age makeup (Table 4) and in the size of fish of the same age (Table 5). The char's rate of growth increases with age and reaches an absolute maximum at 6-10 years, and falls off by 24 years (Fig. 7). The char grows mainly in the summer, but linear growth of the migratory char continues even in the winter due to the accumulated reserve nutrients, which is indicated by the considerable loss of weight over the winter. The rate of growth of the migratory char is higher than that of the lake char (Table 6).

The population may show a broad range of variations in age and length. A bimodal distribution, particularly, the existence together of dwarf and fast-growing individuals, is characteristic of the char of many lakes. The migratory

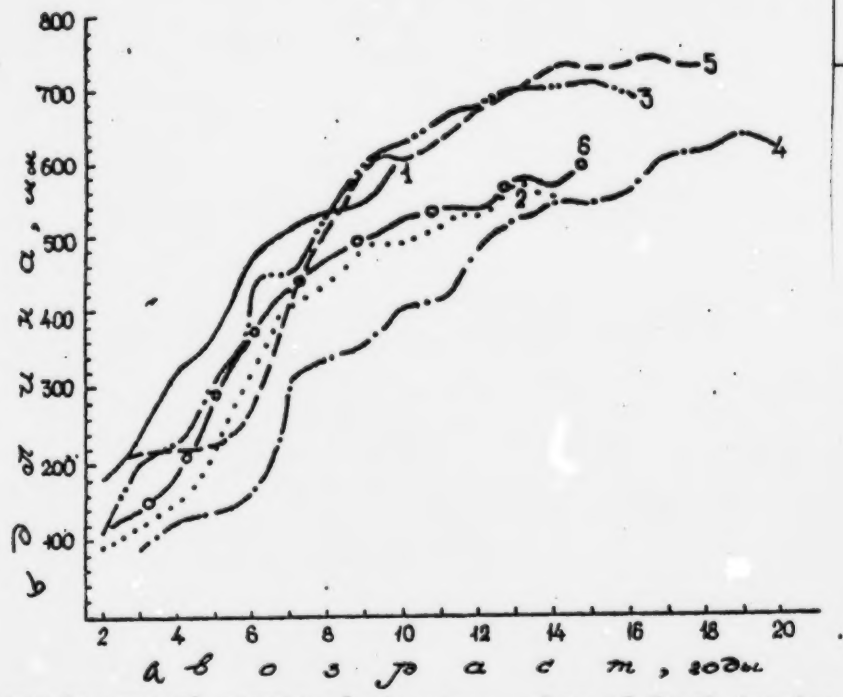

Fig. 6. Comparative growth curves of migratory char of North America (Dempson, Green, 1980).
1) Middle Brook, Labrador (54°23' 58°05'); 2 - Fraser R., Labrador (53°39' 64°10'); 3) Leaf R. (Ungava Bay (58°47' 70°04'); 4 - Sylvia Grinnell, Baffin I. (63°44' 68°34'), 5) Neivik*L., Kent Peninsula (68°15' 107°25'), 6) Sagavanirktok*, Alaska (70°00' 148°00').
a - age, years; b - length, cm.

char also shows a similar distribution. Great variation in age and length is a phenomenon common to freshwater and migratory char. For example, a char with body length 43-48 cm may vary in age by as much as 8 years (Fig. 7).

Spawning. The times and nature of the spawning of the char have still not been fully studied, but from the findings known, we may say that there is no single picture of spawning for all chars.

The char spawns several times in its life. The frequency of spawning may vary with increase in age and size (Kolyushev, 1973). The dates of first spawning and spawning places vary more widely in the char than perhaps any other salmon. In the migratory char, the age of first spawning varies from 4-10 years (Table 3). Nonmigrating char populations as a rule reach maturity at a lesser size and a lesser age than the migratory char (Table 7). In Northern Norway,

/15

TABLE 5

Length of char of different age from the rivers of Northern Labrador, cm. (Andrews, Lear, 1956).

Возраст, гг. 1	Эдлатток 2	Найн 3	зал. Окках 4	Хеврон 5	Рамах 6
5	44.5	-	-	-	-
6	48.2	39.8	-	-	-
7	49.9	44.9	41.8	47.0	41.2
8	55.7	47.6	44.0	47.6	42.3
9	57.0	49.7	45.4	48.7	44.2
I0	58.4	50.I	45.3	49.5	47.2
II	62.6	50.6	45.0	50.6	47.8
I2	62.5	54.2	47.4	5I.4	49.5
I3	65.6	54.2	48.2	5I.5	50.3
I4	-	-	-	47.6	60.8
I5	-	-	-	-	57.I
I6	-	-	62.0	-	76.4

1 - age, years; 2 - Adlatok; 3 - Nain; 4 - Okak Bay; 5 -Hebron; 6 - Ramakh*.

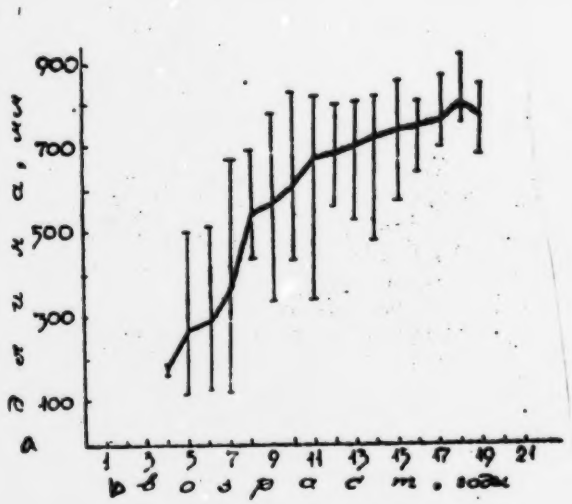

Fig. 7. Length of char of different age, caught in Neivik* L. (Johnson, 1980), a - length, cm; b - age, years.

some individuals mature at a length of 100 mm and age two years (Martin, 1955). /13
However, even among the lake char, populations are to be found that mature at 7-17 years, but it is difficult to distinguish the age of maturation of the different groups in those places where the migratory and lake forms of char coexist.

The time of spawning is also extrmely varied. In some regions, the char /14 may spawn in both the fall and spring, sometimes even in the summer and winter. But most often spawning occurs in the fall.

The spawning run of the migratory char males and females may differ. The males arrive at the spawning grounds somewhat earlier than the females. The females do not appear until later and depart after spawning sooner than the males. The average duration of spawning is 11.4 - 12.6 days for males. The spawning duration varies at different spawning grounds. At some spawning grounds, diurnal migrations have been noted, and the males arrive later than the females (in the evening) for spawning. The char spawning grounds may be situated in both rivers and lakes. In rivers, the char spawns in korgi (stone-covered pools) in lakes on stony-pebbly bottom, at a depth of up to 15 m; spawning takes place less often on coarse sandstone. In rivers, the char spawns on reaches with slow current (0.2 to 0.4 m/s). The water temperature during spawning may vary from 1.5 to 7°. In those places where the rivers freeze over completely in the winter, spawning takes place in the lakes.

It has been shown in numerous experiments that the char in the great /18 majority of cases returns to its habitual spawning growns. Some fishes were removed from the spawning places two or three times and still continued to return each time to their spawning grounds. It is considered that the char has a pronounced "homing" to its spawning places. It is possible that the char

TABLE 6

Length of char of different age in some populations (Johnson, 1960), mm.

Возраст	оз. Неттилинг	р. Сильвия Гринелл	р. Джорджа	Терм Пойнт	зал. Кресвел до 450 мм	зал. Кресвел свыше 450 мм	оз. Уиллоу	оз. Нейвик	р. Сагаваниритон	р. Сенд-Хил	р. Рамах	Кратер Унгава	оз. Коровattнат	оз. Коровattнат (карлики)	оз. Чар	оз. Кайхол	оз. Матамек
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
0												49					
1		14					89					74	110	80	80		
2	67	28					93			238		102	200	100	70	123	
3	78	50					122	225		248		116	280	130	89	189	
4	90	80		318			162	239		316		153	300	170	100	193	183
5	90	116		381			189	234		466			340		100	213	172
6	190	154		406	300		228	278	473	502	412	230	400	280	110	227	188
7	231	196	473	445			319	416	489	814	423	280	420	290	125	246	232
8	244	240	499	468	355			510	477	816	442	412	570	310	149	274	307
9	258	286	512	494	310			601	522	480	472	368	600	330	140	299	328
10	335	335	541	523	336	530		606	532		478	480			145	306	368
11	333	382	579	565	304	533		653	569		495	365			150	316	414
12	345	427	613	602	349	494		676	582		503	445			150	328	480
13	392	468	652	639	383	548		694	569		606	496			180	333	626
14	385	503	650	638	341	866		728	872		671	850			168	344	900
15	433	563	728		386	852		721			764				168	381	438
16	474	586			357	888		742							178	350	
17	448	604			384	818		736							186	328	
18	475	623			392	575		724							220	361	
19	484	639			398	621									226		
20	540	653			358	650									260		
21	480	664			419	645											
22		675			410	669											
23		685				740											
24					400	665											
25						690											
26						673											
27						633											
28						640											
29						700										3478	92
30																	
Количество рыб	286	680	237	95	161	282	228	264	80	77	110	53					

Key: 1 - age; 2 - Nettiling L; 3 - Sylvia Grinell R.; 4 - Georgie* R.; 5 - Term Point*; 6 - Creswell Bay; 7 - up to 450 mm; 8 - more than 450 mm; 9 - Willow L.; 10 - Neivik* L.; 11 - Sagavaniritok R.; 12 -Sand Hill R.; 13 - Ramakh R.*; 14 - Ungava Crater; 15 - Korovattnat* L.; 16 - Char*L.; 17 - Keyhole* L.; 18 -Matamec L.; 19 - number of fishes.

TABLE 7

/17

Characteristics of nonmigratory populations of arctic char (Johnson, 1980).

Место обитания (1)	Пол (2)	Возраст созревания, лет (3)	Длина при созревании, мм (4)	Средний вес, г (5)	Плодовитость (6): абсолютная (7)	Плодовитость (6): относительная (8)
(9) оз.Лейскарелва, Норвегия	♂	3				
	♀	7	216–268	–	461	–
(10) Виндермере, Великобритания						
(11) осенненерестующие	♂	5–9	110–330	–	–	–
	♀	5–9	140–330	288	1220	425
(12) весненнерестующие	♂	5–9	140–385	–	–	–
	♀	5–9	170–350	331	1720	544
(13) карлики	♂♀	4	155–180	–	–	–
(14) оз.Матамек, Канада		3–8	299–480	720	1973	249
	(15)	ср.4.7				
(16) Кратер Унгава, Канада		14–18	477–554	–	–	–
(17) Лагерный пруд	♂	2	76–124	–	–	–
	♀	2–3	96–132	–	40–200	–
(18) Северный пруд	♂	2–13	93–502	–	–	–
	♀	2–11	101–480	–	21–41	–
(19) оз.Неттилинг, Канада	♂	7–21	180–520	–	–	–
	♀	8–19	355	395	1135	284
(20) оз.Фиона, Канада			130	23	48	209
(21) оз.Кейхол, Канада	♂	3–17	106–405	–	–	–
	♀	7–14	156–406	330	610	185
(22) Система Факсалвен, Швеция						
(23) Блашон IV	♀		230	115	451	392
(24) Лейпикваттнет II	♀		330	335	1519	453
	♀		400	550	3103	564
(25) оз.Гаденское, ФРГ	♀	3–5	262	150	900	970
	♀		375	430	2000	430

Key: 1 - habitat; 2 - sex; 3 - age of maturity, years; 4 - length at maturity, mm; 5 - average weight, g; 6 - fecundity; 7 - absolute; 8 - relative; 9 - Leiskarelva*L., Norway; 10 - Windermere, Great Britain; 11 - fall-spawning; 12 - spring-spawning; 13 - dwarfs; 14 - Matamec L., Canada; 15 - av. 4.7; 16 - Ungava Crater, Canada; 17 - camp pond; 18 - northern pond; 19 - Nettiling L., Canada; 20 - Fiona* L., Canada; 21 - Keyhole*L., Canada; 22 - Faksalven* System, Sweden; 23 - Blashon*IV; 24 - Leipikvattnet*II; 25 - Gadensk* L., West Germany.

in traveling to spawn from the sea finds its native river by means of the pheromones excreted by freshwater individuals or smolts migrating downstream (Nordeng, 1961).

The char builds nests consisting of depressions of roughly round shape in the gravel bottom, from 2 to 3 m in diameter. The males fight fiercely at the spawning grounds. One victor male may fertilize the roe of several females (Fabricius, Gustafson,1954). In those lake-river systems where both the migratory and freshwater chars live, they mix at spawning. Tables 3 and 7 show data on the feucndity of migratory and lake char of different populations.

Feeding. The food of the char is the most varied. In fresh water, it is predominately representatives of bottom fauna and plankton that are found in fish stomachs. Chironomid larvae and gammaruses predominate among the benthic organisms that serve as food for the char in many bodies of water. Small molluscs are found. The nature of feeding is also determined by the ecological niche that the char occupies. In char that inhabit the bottom sublittoral zone of lakes, representatives of bottom fauna predominate. In the pelagic char, however, various forms of plankton, insect larvae and aerial insects have been found in stomachs..

The roe of the char itself and of other salmon is the main component in char stomachs at spawning grounds. Among the representatives of the ichthyofauna that serves as a food object for the char in freshwater, we may note the perch, the stickleback, the minnow, the sculpin, and juveniles of eels and other fishes (Johnson, 1980).

At sea, the char feeds on fish and large crustaceans (Table 8).

These data from the scientific literature show that this species is /19 very variable. Even in adjacent populations, great differences have been found in fish characteristics. Annual variations in the characters of the same char population also exist. In order to characterize the arctic char of

/18

TABLE 8

Composition of food of Labrador char in July-August, 1953, % by volume (Andrews, Lear, 1956).

Стадо 1	Мойва 2	Песчанка 3	Остроносый триглопс 3а	Ракообразные 5
Эдлэток	88	3	0	0
Найн	I5	I3	6I	II
зал. Окках	99	0	0	I
Хеврон	3	0	I5	8I
Рамах	4	I4	25	56

Key: 1 - population; 2 - washer; 3 - sand lance; 3а - "sharp-nosed" sculpin; 4 - crustaceans; 5 - Adlatok; 6 - Nain; 7 - Okak Bay; 8 - Hebron; 9 - Ramakh*.

/19

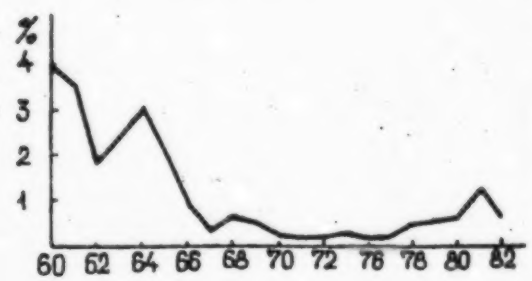

Fig. 8. Percentage of char in make-up of study catches of lake fish in Murmansk oblast (based on tabular data of Nelichik, 1985). Y-axis - % of char in catch; X-axis - year of catch.

of a particular region, one must thus have at hand very extensive data, gathered over a long time. Data on the chars of the Soviet north are unfortunately fragmentary.

3. The char of the Kola Peninsula

The arctic char on the Kola Peninsula is represented by both the lake and the migratory forms.

The lake char. It is found in the large lakes of the Terskii coast: Imandra, Umbozero, the Pirengsk lakes, and Kondozero reservoir (Galkin, 1966). M.I. Vladmirskaya (1957) found the char in five lakes of the Lapland sanctuary, A.G. Chernitskii and A.A. Loenko (1983) in L. Nizhnee Luven'gskoe. On the Murmansk coast, the char is found in many lake-river systems connected with the sea. The arctic char plays a small role in catches of lake fish (Fig. 8). The char form different forms in almost every lake (hence the variety of local names: golets, paliya, nergas, nereus, rauda).

In Kumuzh'e L., invertebrates predominate in the feeding of the paliya :water-fleas, amphipods, chironomid and dragonfly larvae. Because of the forced feeding on invertebrates, the growth of these fishes is very slow, and they form a dwarf form here. The golets from Verkhnii and Nizhnii Raichor"yaurench lakes, that feed mainly on crustaceans and insects, has relatively slow growth (Tables 9 and 10).

The paliya (or nergas) of Kondozero has large size. According to information from fishermen, the nergas reaches a weight of 6-8 kg and a specimen weighing 12.3 kg was caught only once in 1961. The good weight of the paliya is due to the abundance of food objects. In connection with its predatory mode of life, this paliya grows more rapidly than other valuable fishes of the Kola /20

/20

TABLE 9

Age and size of arctic char from the Raichor"yaurench lakes (Vladimirskaya, 1957).

Озеро 1	Возраст 2					
	5+	6+	7+	8+	9+	I4+
Нижний 3 Райчоръяуренч	325 667	-	370 670	380 690	-	360 560
Верхний 4 Райчоръяуренч	-	-	-	290 405	360 480	-

Key: 1 - Lake; 2 - age; 3 - Nizhnii Raichor"yaurench; 4 - Verkhnii Raichor"yaurench.

Note: Length in mm above the line; weight of char, g, below.

TABLE 10

Feeding of char in the Raichor"yaurench lakes in early June, 1952, frequency of occurrence, % (Vladmirskaya, 1957).

Пища 1	Нижний Райчоръяуренч 2	Верхний Райчоръяуренч 3
Черви 4		
Oligochaeta	II.0	-
Моллюски 5	50.0	I00
Limnaea	-	I00
Planorbis	I2.4	-
Pisidium	37.0	-
Ракообразные 6	I00.0	-
Euricercus	25.0	-
Gammarus	I00.0	-
Насекомые 7	88.0	I00
Подёнки 8	-	I00
Вислокрылки 9	33.0	I00
Ручейники I0	45.0	I00
Мотыль (куколки II и личинки Criptohironomis camptolabis, Pelopiinae, Proeladius)	67.0	I00
Растительные остатки I2	II.0	-

Key: 1 - food; 2 - Nizhnii Raichor"yaurench; 3 - Verkhnii Raichor"yaurench; 4 - worms; 5 - molluscs; 6 - crustaceans; 7 - insects; 8 - May-flies; 9 - alder and snake flies; 10 - caddis-flies; 11 - bloodworm (pupae and larvae of Criptohironomis camptolabis, Pelopiinae, Proeladius); 12 - plant remains.

/21

TABLE 11

Size and weight of paliya (char) by age groups (Galkin et al., 1966).

Озеро и форма гольца	Количество рыб	Возраст, лет					
		2+	3+	4+	5+	6+	среднее
		Длина по Смитту, см					
Имандра, голец	94	27.9	32.8	36.9	41.1	45.0	36.2
Умбозеро, голец	52	25.2	33.6	37.1	40.7	45.9	37.3
Умбозеро, палия	131	27.5	33.9	35.9	38.6	54.9	36.0
Кумужье, палия	3	-	-	27.1	29.0	-	27.3
Кондозеро, нерга	10	-	39.2	47.5	50.2	50.9	49.2
		Вес, г					
Имандра, голец		- 238	398	675	827	1096	568
Умбозеро, голец		- 185	440	671	799	1195	688
Умбозеро, палия		- 247	490	625	808	2800	645
Кумужье, палия		- -	-	210	340	-	250
Кондозеро, нерга		- -	600	1025	1331	1680	1235

Key: 1 - lake and form of char; 2 - number of fish; 3 - age, years; 4 - average; 5 - Imandra, golets; 6 - Umbozero, golets; 7 - Umbozero, paliya; 8 - Kumuzh'e, paliya; 9 - Kondozero, nergas; 10 - Schmidt's length, cm; 11 - weight, g.

Peninsula. The paliya usually becomes sexually mature in the fourth year of life (3+) at a body length of about 30 cm and weight about 400 g. In the slow-growing forms, sexual maturity sets in later - in the fifth year (Table 11). /20

The average fecundity of the Imandra golets is 1940 eggs (1300-2900), that of the Umbozero golets - 1600 (955-2609), the paliya 2570 eggs. The paliya spawns in the lake itself on korgi, at a depth of 3-10 m. Their spawning takes place at the end of August - beginning of September, and in Umbozero in the second half of September on korgi. /21

Paliya fingerlings and yearlings keep to deep places - up to 30 m - at the bottom, where they feed mainly on the relict crustacean Pontoporea. The

second-year juveniles make a transition to predatory feeding on cisco larvae and fry. The large golets feeds exclusively on cisco in both Imandra and Umbozero. Eel fry make up the bulk of the diet of the paliya of Umbozero (Galkin et al., 1966).

The migratory char is found in many rivers, but does not form numerous stocks. The arctic char of the Varzina R. is considered to be the most numerous, but only two works have been devoted even to it (Nesterov, 1985; Savvaitova, Tsarev, 1986).

The age of the Varzina R. char is 6-16 years (Table 12), length 34-60 cm, weight 0.4 - 2.4 kg (Table 13).

V.D. Nesterov (1958) cites findings indicating that the migration of the char into the Varzina R. begins in the second half of July and continues until the middle of September. Fish with gonads in maturity stages III-IV enter the river until August 20th, later, fish with poorly developed sexual products.

/ 22

TABLE 12

Age makeup of migratory char of Varzina R., % (Nesterov, 1985).

Пол (1)	Количество экз. (2)	Возраст, лет (3)										
		5+	6+	7+	8+	9+	10+	11+	12+	13+	14+	15+
Самцы (4)	52	3.8	11.5	11.5	26.9	7.7	7.7	21.2	5.9	3.8	-	-
Самки (5)	16	-	12.6	6.2	6.2	18.8	12.5	18.8	-	6.2	12.5	6.2
Оба пола (6)	68	2.9	11.8	10.3	22.1	10.3	8.8	20.6	4.4	4.4	2.9	1.5

Key: 1 - sex; 2 - number of specimens; 3 - age, years; 4 - males; 5 - females; 6 - both sexes.

TABLE 13

Length and weight of the Varzina R. char (Nesterov, 1985.

Возраст	Количество	Длина, см	Вес, кг
5+	2	39.4	0.65
		34.9 - 43.8	0.4 - 0.9
6+	8	45.7	I.06
		39.5 - 52.5	0.7 - I.6
7+	7	47.4	I.20
		4I.0 - 54.3	0.7 - I.7
8+	I5	46.5	I.I0
		4I.7 - 52.8	0.7 - I.8
9+	7	46.5	I.I5
		4I.2 - 50.5	0.8 - I.5
I0+	6	49.8	I.34
		44.7 - 54.4	I.I - I.7
II+	I4	52.4	I.60
		42.5 - 58.7	0.8 - 2.4
I2+	3	55.3	I.98
		53.I - 57.6	I.8 - 2.3
I3+	3	54.3	I.70
		53.8 - 54.6	I.6 - I.8
I4+	2	57.6	2.25
		55.6 - 60.0	2.25
I5+	I	55.0	2.0

Key: 1 - age; 2 - number; 3 - length, cm; 4 - weight, kg.

Note. Average value above the line; limits of variation below the line.

4. The char of the Novaya Zemlya Is. /23

Russian fishermen from the shores of the White Sea and from Pechora Kray first appeared in Novaya Zemlya probably in the XV C. It was apparently at that time that together with marine animals and birds, they began to hunt he arctic char as well. However, the first scientific data on the biology of the Novaya Zemlya char were obtained in 1931 and 1932 during the work of the

Novaya Zemlya scientific-commercial expedition of the Arctic Institute under the supervision of V.K. Esipov. The results of the works of this expedition, published in 1935, have remained to this time the only source of information on the biology of the arctic char of the Novaya Zemlya Is.

The life cycle of the Novaya Zemlya char is governed by the severe conditions in which it lives: the poverty of the freshwater food base and the low winter temperatures at sea. The char must therefore migrate to sea for fattening and to the unfrozen deep lakes of the archipelago for wintering.

The char juveniles spend the first 3-4 years of life in fresh water. Data on this period are very few. L.O. Retovskii (1935) cites the finding of fingerlings in small lakes and rivers connecting the lakes with the sea.

Analysis of the feeding of 32 fingerlings showed that the food includes freshwater crustaceans and insect larvae, as well as adult mosquiotoes and flies. The small fry feeds on bottom objects, and aerial insects are found only in the stomachs of the large forms (Retovskii, 1935). The fingerling grows to 11-27 cm over the freshwater period (Fig. 9). Beginning at age 3-4 the char migrates annually to the sea for fattening.

The arctic char migrates to the sea in the spring. V.K. Esipov (1935) does not cite data on the specific dates of the downstream migration of the juveniles. At least 4 years passes from the first migration to sea until maturity, and the char returns for wintering in each of these years.

The arctic char grows quickly at sea (Fig. 10). There are no data on the biology of the char during the marine period of its life. V.K. Esipov considers that the foraging char does not go far from the mouths of rivers, but analysis of parasite fauna of the Novaya Zemlya char gives grounds to suppose long marine migrations of these fishes as well (Mitenev, Shul'man, 1986).

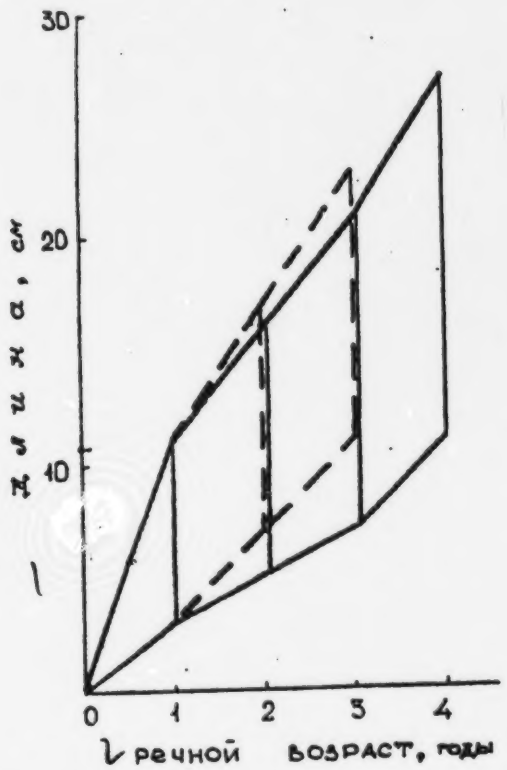

Fig. 9. Growth of the char migrating to sea at 3 years - dashed line, and 4 years - solid line (based on tabular data of Slastnikova, 1935),

1 - length, cm; 2 - river age, years.

TABLE 14

Distribution of migratory char in the Nekhvatova R, by sex and maturity stage,% (1986).

1 Пол	2 Стадии зрелости		
	II	III	IV
3 Самцы (135 экз.)	87	8	5
4 Самки (155 экз.)	85	15	0

Key: 1 - sex; 2 - stages of maturity; 3 - males (135 spec.); 4 - females, (155 spec.).

Fig. 10. Growth of Novaya Zemlya char at sea (based on tabular data of Slastnikov, 1935.

1 - length, cm; 2 - marine age, years.

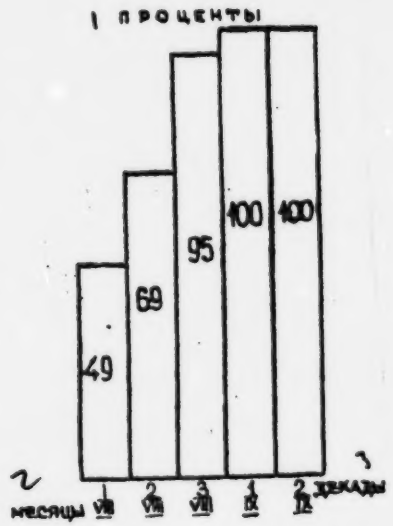

Fig. 11. Percentage of sexually immature fishes in char catches in Krestovaya Bay in 1931 (Esipov, 1935).

1 - percentages; 2 - months; 3 - ten-day period (of month)

The char returns from the sea to the lakes starting in the second ten-days of August. /23 Those individuals that will spawn in the current year go into the rivers of Krestovaya Bay. Their migration is completed at the end of August, and in September they turn up only singly. The fish that omit spawning in the current year enter the rivers in the second half of August; the maximum of /24 their migration is noted in the first few days of September (Fig. 11). The migration is completed by the middle of September, and it is made by small fishes that have spent one or two years at sea. The dates of the migration may be different in other rivers of Novaya Zemlya.

Our observations of the char migration in the Nekhvatova R., made in the first week of September 1986 showed the following distribution of the migrating fish by sex and stage of maturity (Table 14).

There are no observations on the spawning of the char in Novaya Zemlya. V.K. Esipov (1935) surmised indirectly that the spawning of the char occurs in October-November and not in the rivers, which are shallow at this time and easily freeze, but in the lakes.

The appearance and physiological condition of the maturing fishes change - /25 the post-spawning condition sets in. The immature fishes have a silvery-green body coloring; the maturing fishes have spots on the sides, a pale-red abdomen, orange-red or golden fins, a lighter-colored and less fatty meat, and a lower jaw that is bent up somewhat.

The fecundity of the Novaya Zemlya char varies from 1,500 to 9,000 eggs, average 3,500. Table 15 shows the fecundity indices of individual fishes.

Age and growth. Trap net catches in 1931 by a scientific-commercial expedition in Krestovaya Bay (Slastnikov, 1935) showed the following picture

of distribution of the fishes by age groups: 54% of the fishes had river age 3 years, 46% - 4 years. The marine age varied from 3 to 8 years.

Age	% of fishes
3+	18.4
4+	63.2
5+	4.8
6+	8.0
7+	4.0
8+	1.6

Table 16 shows the distribution by age of 108 specimens of migratory char from the Nekhvatova R. These findings show that fish with river age 3+ predominated in both rivers. It is difficult to compare the marine age of the fish, since only the end of the run, in which small char took part, was studied in the Nekhvatova R. The changes in fish length with age are shown in Fig. 10.

/26

TABLE 15

Fecundity of Novaya Zemlya char (Esipov, 1935).

Длина тела, см (1)	Масса, кг (2)	Стадия зрелости (3)	Вес гонад (4)		Плодовитость (7)	
			абсолютный, г (5)	относительный, % (6)	абсолютная (5)	относительная (6)
53.0	I.75	IУ	I68	9.6	2789	I594
53.5	2.07	IУ	I35	6.5	2466	II94
56.0	I.86	Ш-IУ	88	4.7	I407	748
56.I	2.38	IУ	I77	7.4	2855	I202
57.0	2.I0	Ш-IУ	I08	5.I	3240	I543
57.0	2.I6	Ш-IУ	I68	7.8	2956	I368
57.0	2.73	Ш-IУ	I58	5.8	3592	I3I5
57.2	2.04	IУ	259	I2.7	4409	2I66
58.2	2.34	Ш-IУ	I55	6.6	2604	IIII
58.8	2.50	Ш-IУ	I40	5.6	3227	I293
59.0	2.57	Ш-IУ	I60	6.2	3480	I356
73.3	3.95	Ш-IУ	355	9.0	9058	2296

Key: 1 - body length, cm; 2 - mass, kg; 3 - maturity stage; 4 - weight of gonads; 5 - absolute, g; 6 - relative, %; 7 - fecundity.

TABLE 16

Age makeup of char catches in Nekhvatova R. (Slastnikov, 1935).

Речной возраст 1	Количество, % 2	Морской возраст 3			
		0+	I+	2+	3+
3	56	37	I4	4	I
4	44	32	I0	2	0

Key: 1 - river age; 2 - amount, %; 3 - marine age.

TABLE 17

Size-age makeup of char catches in Nekhvatova R. and Krestovaya Bay, cm.

Речной возраст 1	2 Морской возраст					
	3+	4+	5+	6+	7+	8+
3	46.3	52.7	52.0	68.8	6I.8	64.7
4	45.9	52.6	57.6	60.8	-	73.3

Key: 1 - river age; 2 - marine age.

/27

TABLE 18

Weight of char of Krestovaya Bay, g.

Речной возраст 1	Морской возраст 2					
	3+	4+	5+	6+	7+	8+
3	II86	I726	I598	2I42	2385	23I0
4	II24	I750	2207	2840	-	3945

Key: 1 - river age; 2 - marine age.

TABLE 19

Length of char of Nekhvatova R., cm

Речной возраст 1	2 Морской возраст			
	0+	I+	2+	3+
3	24.3	30.9	40.6	54.0
4	25.0	30.8	38.5	-

Key: 1 - river age; 2 - marine age.

TABLE 20

Weight of char in Nekhvatova R., g.

Речной возраст	Морской возраст			
	0+	+I+	2+	3+
3	I57	330	755	I2I0*
4	I7I	350	7I8	-

Key: 1 - river age; 2 - marine age.,

* Original reads "2I0"; obviously a misprint.

TABLE 21

Size-age indices of Novaya Zemlya char (based on data of Murmansk Marine Biology Institute, 1966),

Река	Количество экз.	Длина, см	Вес, кг	Упитанность (по Фультону)
Гусиная	25	49.6±I.I	I.57±0.I0	I.28±0.03
Нехватова	88	47.4±0.7	I.3I±0.07	I.I6±0.02

Key: 1 - river; 2 - number of specimens; 3 - length, cm; 4 - weight, kg, 5 - Fulton's condition factor; 6 - Gusinaya; 7 - Nekhvatova,

Tables 17-20 show the length and weight of fish of different age /26
from catches in Krestovaya Bay and the Nekhvatova R. (Slastnikov, 1935),

An expedition of the Murmansk Marine Biology Institute in 1986 studied /27
the char in two rivers: the Pukhovaya and the Nekhvatova, Table 21 shows the size-age indices from our catches,

There are no data on the size-age characteristics of the char of the Kara coast of Novaya Zemlya, except for the results of the study of 76 fishes from Brandt Bay (Esipov, 1952). The length of the fishes was 53,4 cm on average

(32 - 75 cm), weight 1.845 (0.4 - 5 kg). The age did not exceed 14-15 years. On the basis of oral communications which we received from Novaya Zemlya fishermen, the weight of the char from the rivers of the eastern coast can reach 15 kg.

Feeding. At sea the char feeds mainly on fishes, to a lesser extent on crustaceans (Table 22). Our observations in September 1986 showed that the char in the estuary zone of the Nekhvatova R. fed very intensively; stomach fulness was 5 points. Cod fry, coalfish, sand lance and amphipods predominated /28 in contents.

TABLE 22

Makeup of food of char caught in Krestovaya Bay (Esipov, 1935).

Component	Frequency of occurrence, %
Cod	28
Gadidae	16
Washer	6
Sand lance	5
Gobies and their fingerlings	3
Fish fingerlings (not cods)	13
Unidentified fishes	2
Fish eggs	1
Crustaceans	7
Amphipods	6
Worms	5
Others	8

5. Breeding of char in aquaculture

Thanks to its high consumer qualities, the arctic char has become /28
not only a target of the fishery, but also an object of fish culture. Both the lake and the migratory char is bred. The former is bred mainly in the Alps, while the latter most successfully in Norway. It is known that the char is considered to be a more promising object of sea farming than the Atlantic salmon in the northern provinces of Norway (Braaten, 1985). Unfortunately, the published data on the biotechnology of char breeding are even scarcer and more fragmentary than those on its biology.

Rearing of the lake char. In alpine lakes, the char is cultivated in tanks. Contrary to widespread opinion, the char survives not only in pure oligotrophic bodies of water, but also in rather eutrophized ones. The lake char is less sensitive to water temperature and oxygen content than to biotechnical factors (Pohlhausen, 1984). The rate of growth of the char in tanks is high; the fishes' weight can treble over the winter. To prevent the formation of ice in the winter and to improve the quality of the water in the tanks, it is recommended that deep waters lying below the thermocline and having a temperature of $+4^{\circ}$ be raised to the surface (Pohlhausen, 1985).

Studies of Austrian fishermen have established a number of factors /29
than influence the effectiveness of roe incubation (Steiner, 1984). It has been shown that the size of the females from which it has been obtained does not affect the survival of the roe; very small and young fishes are an exception. Differences in roe size, if they are associated with differences in the size of the females, do not affect the survival rate of the roe. But when roe of different size obtained from the same female is cultivated, the large roe has better culture indices.

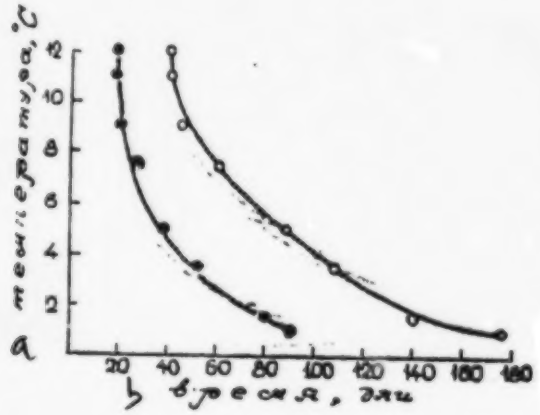

Fig. 12. Roe development time at different temperature (Steiner, 1984). Lower curve - eye stage, upper curve - hatching. a - temperature, °C; b - time, days.

Water temperature influences the duration of incubation. Figure 12 shows how the char roe development rate is influenced by temperature. An excessively high or excessively low temperature, however, leads to an increase in mortality (Fig. 13), and therefore a temperature of 3.5 - 8° is accepted as optimal.

At the Polar Scientific Research Institute of Marine Fisheries and Oceanography (PINRO), instructions on the rearing of lake char have been developed on the basis of the experience in work with the Imandra Lake char (Terekhin, 1984). These instructions include the stages of stocking of spawners, obtaining and fertilizing roe, its incubation and work with larvae and fingerlings. The larvae obtained are released into the lake to replenish the population existing there.

In rearing the migratory char, a basic problem is the creation of a brood stock. Work in this direction was done in Canada, where fry, grown from

migratory parents, was cultivated until the achievement of sexual maturity (Papst, Horky, 1984). A set-up with 90% of the water recirculated was used for this. Trout mixtures were used as food for the char, but the ration was 1.5 times higher. As a result, the chars achieved sexual maturity 2.5 - 3 times faster than in the original population. However, the culture indices of the brood stock were poorer (Table 23).

/30

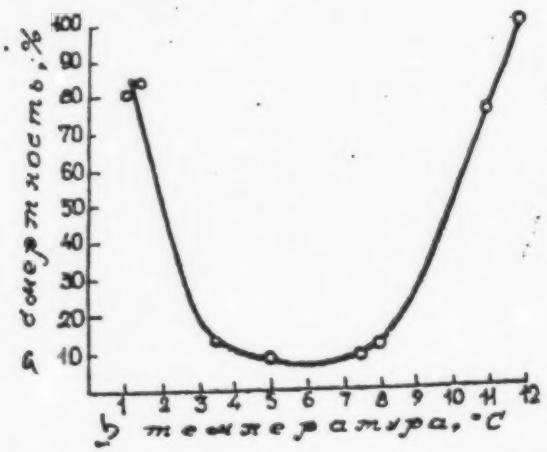

Fig. 13. Mortality rate of incubated roe at different temperature (Steiner, 1984). a - temperature, °C; b - mortality rate, %.

TABLE 23

Comparative characteristics of spawners from natural conditions and brood stock (Parst, Horky, 1984).

1 Группа	2 Возраст, лет	3 Размер, мм: 4 самцы	5 самки	6 Абсолютная плодовитость	7 Диаметр икры, мм
8 Природная популяция	I0-I2	550	750	4781	5.I
9 Маточное стадо	4	49I	493	I769	4.9

Key: 1 - group; 2 - age, years; 3 - size, mm; 4 - males; 5 - females; 6 - absolute fecundity; 7 - roe diameter, mm; 8 - natural population; 9 - brood stock.

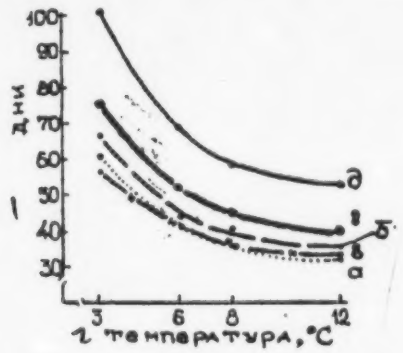

Fig. 14. Time of achievement of basic stages in the development of larvae incubated at different temperature (Wallase, Aasjord, 1984).
a - floating up of first larvae; b - floating up of 50% of larvae; c - feeding of first larvae; d - feeding of 50% of larvae; e - resorption of yolk sac.
1 - days; 2 - temperature, °C.

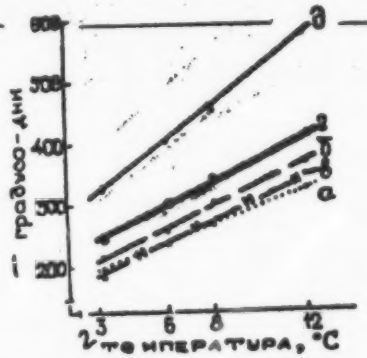

Fig. 15. Duration of achievement of main stages in larval development in degree-days (Wallase, Aasjord, 1984). Symbols same as in Fig. 14.
1 - degree-days; 2 - temperature, °C.

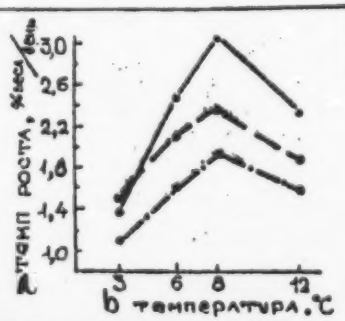

Fig. 16. Rate of growth of larvae maintained at different temperature (Wallase, Aasjord, 1984). a - growth rate, %weight/day; b - temperature, oC.

The mortality rate of the roe obtained from the brood stock was 7 /30
times higher than that from the wild spawners. One reason was the low fertilization percentage, another may have been the smaller size of the roe obtained from the brood stock. It has been shown that in the migratory char in Northern Norway (Lake Storvatn) that larger larvae also appear from larger roe (Wallase, Aasjord, 1984). The large larvae survive better and grow more rapidly and this pattern is typical of all salmon (Chernitskii, 1986). However, the number of deformed larvae was higher in that group of char which was obtained from large roe (Wallase, Aasjord, 1984). The same authors studied the problem of the transition of char larvae to active feeding and the effects of water temperature on the growth, development and survival of larvae. As also in the case of the above-described experiments with the lake char, it has been shown that development is accelerated by higher temperature (Fig. 14), although when the duration of development in degree-days is compared, it turns out that the fish developing at lower temperatures are characterized by a shorter duration of development than the fish developing at the higher temperatures /31
(Fig. 15). The rate of growth was highest in the fish cultivated at a temperature of 8° (Fig. 16). But the fish developing at a temperature of 12° had the highest mortality rate (Table 24).

The optimal temperature for rearing char larvae, ensuring both rapid growth and a good survival rate, these authors therefore consider to be $6\text{-}8^{\circ}$. Thus, these data are in good agreement with the above-mentioned results obtained in the experiments with lake char,

The first experiments in the rearing of char in sea water, which were done in Norway in 1974, were unsuccessful (Gjedrem, 1975). In June, 1974, two groups of migratory char smolts, obtained from parents from two different rivers, were

placed in marine tanks, in which the water had a salinity of 32-35%. In June /32
and July, the fish grew normally, but the mortality rate of the fish of the first group increased sharply from the middle of August. No diseases of any kind were found in the dead fish. Those fish which were then transfered to brackish water, survived, while those which remained in the salty water died in September. The fish of the second group continued to grow until the middle of September, but later also died. Only 4% of all fish remained alive in January, but their condition was very poor. The mortality was due to the combined influence of the low temperature and high salinity of the sea water in the fall-winter period. Thus, the mortality rate of the char was sufficiently low in the summer in both sea and freshwater (2.2 and 2.6%, respectively). In the winter, the mortality rate of the fish in the sea water was 58%, and in freshwater 14% (Wandswik, Jobling, 1982). It was primarily those fish that grew slowly in the sea water in the summer that died in the fall-winter. Only 18% survived in the group with summer increment of 1,7, while 61% survived in the group with 2,9 increment (Table 25).

The authors explain this by the fact that the slow growth in sea water reflects the poor adaptation of the fish to salt water, and the inability to maintain ionic homeostasis leads to the death of the fish. There are findings indicating that char have a poorer capacity for osmoregulation than other salmon (Roberts, 1971 and others). But there are also contradictory findings. /33
As has been shown by the works of the Murmansk Marine Biology Institute, migratory char juveniles and lake char adult specimens can be transfered abruptly, without gradual adaptation, from freshwater to sea water with a salinity of 34%. The fish adapt themselves well to the new conditions and continue to feed (Kamshilov, 1961). The question as to the causes of the mortality of the char in sea water in the winter thus remains an open one. One of the Norwegian investigators (Andersen, 1976) explained the

TABLE 24

Mortality rate of migratory char larvae reared at different temperatures (Wallase, Aasjord, 1984, abbreviated).

Температура, °C 1	Смертность личинок на ранних стадиях, % 2	Смертность личинок, не сумевших перейти на активное питание, % 3
3	I.I	0.2
6	0.3	0
8	0.3	0.3
I2	5.I	43.5

Key: 1 - temperature, oC; 2 - mortality of larvae at early stages, %; 3 - mortality of larvae that had not made the transition to active feeding, %.

TABLE 25

Number of char dying when reared in sea water, spec. (Wandsvik, Jobling, 1982).

Вес рыб в сентябре 1	Индекс летнего роста 2	3 Месяц					
		сентябрь 4	октябрь 5	ноябрь 6	декабрь 7	январь 8	февраль 9
До 85 г 10	Ниже I.7 12	5	4	0	5	2	I2
Свыше 85 г 11	"	I	2	0	I	I	3
До 85 г 10	Выше I.7 13	I	0	0	I	3	3
Свыше 85 г 11	"	0	4	I	4	5	I3

Key: 1 - weight of fish in September; 2 - summer growth index; 3 - month; 4 - September; 5 - October; 6 - November; 7 - December; 8 - January; 9 - February; 10 - up to 85 g; 11 - over 85 g; 12 - below 1.7; 13 - above 1.7.

failures that occurred in the first attempts to cultivate the char in sea water /33 by the fact that the experiment described above (Gjedrem, 1975) was done at a latitude of 63°07' N, that is, south of the boundary of the habitat of the migratory char. When the char was maintained in the winter to the north, at a latitude of 70°39', its survival at sea was good (Andersen, 1976). On the basis of reports that commercial marine char has been obtained on a market scale in the northern regions of Norway, and also some advertising materials, we may assume that the difficulties associated with the marine rearing of the char

in Norway have been overcome. But we do not have any concrete data.

6. Directions for immediate studies in the biology of the arctic char and prospects for its utilization in polar sea farming.

The information presented in the preceding sections shows the following.

The arctic char is characterized by a great diversity of intraspecies forms, and it is therefore very difficult to extend findings obtained in one population to other populations, even living nearby. The study of the char populations in the Soviet Union and abroad has been insufficient for a number of reasons: the fish lives in remote undeveloped regions of the Arctic, many stages of its life cycle take place under ice, and because of the insignificance of the fish for fisheries in developed regions.

Solution of the problem of biotechnical utilization of the arctic char in polar sea farming requires more specific information on the biology of this species. The available data allow us to mark out directions for immediate studies.

The main object of study must apparently be the Novaya Zemlya char. Although the data in section 4 indicate a low rate of growth of these fish, which reach a weight of 2-3 kg over several years of marine life, it must be taken into consideration that the annual period of active feeding and growth of the char is only several summer months, while the fish exists for the greater part of the year at the expense of the reserve nutrients accumulated during fattening. This is to say that when the rate of growth of the Novaya Zemlya char is correlated with the length of the fattening period, this index is rather high. /34

The following are the priority tasks for study. In investigating the spawners that go from the sea into rivers, we must establish the size-age structure of the population, the growth rate in the river and at sea, the sex

ratio and the condition of the gonads. We will be able to make a conclusion as to the duration of the commercial rearing of the char, the biotechnological features of its maintenance in the winter and about the possibility of creating brood stocks on the basis of these data.

In investigating migrating juveniles (smolts), we must establish their size-age composition, the dynamics of the migration, and the changes associated with the preparation for the transition to sea water. These data will allow us to draw a conclusion as to the duration of rearing of planting stock in freshwater and the readiness criteria for the transfer of juveniles to sea water.

In future, it will be necessary to do a comparative analysis of the Novaya Zemlya char from different rivers in order to select the optimal populations for culture. Comparison of the char of the Novaya Zemlya Is. with the char of the continental rivers is of definite practical interest. Comparitive analysis of the char smolts and the smolts of other salmon that migrate in the same river (this is the Varzina R. on the Kola Peninsula), will make available data by which to modify the rather well developed biotechnology of Atlantic salmon juvenile culture to the problems of char fry rearing. The results of such a comparison will alschelp to understand the principles of fish adaptation to high latitude conditions.

Once experimental salmon breeding bases have been established by the fish industry in Murmansk oblast, the problems directly connected with biotechnology can be attacked. These problems include the investigation of the freshwater period of the life of the char juveniles in different conditions and study of the development of salt-resistance of juveniles. These findings will then make possible development of an optimal planting stock culture regime, finding ways to reduce the rearing time, and study of the causes of the formation of migratory and freshwater forms in chars. These studies are needed to prevent

the appearance of slow- growing freshwater forms among the reared fish. In addition, the study results will make it possible to assess the possibility of utilizing lake char to create a brood stock and to perfect a regime for the marine cultivation of the char in tanks.

The world salmon farming experience shows that the countries that lead in this field (Sweden in pasture salmon farming, Norway in commercial salmon farming), have achieved this status not only as the result of considerable /35 organizational, financial and scientific efforts, but also largely due to the unique natural features of each of these countries. In the Northern basin, we, perhaps, have at our disposal the most promising form of the arctic char - the Novaya Zemlya char, which will enable us to take the lead in marine salmon farming.

REFERENCES

1. Berg, L.S. Freshwater fishes of the USSR and adjacent countries. Vol. I, Moscow-Leningrad, Publishing House of the USSR Academy of Sciences, 1948, 446 p.
2. Vladimirskaya, M.I. The lake trout, or brook sea trout in the bodies of water of the Imandra L. basin. - Byul. Mosk. o-va ispytatelei prirody, otd. biolg., 1957, Vol. 4, pp 37-51.
3. Galkin, Yu.I., Kolyushev, A.I., Pokrovksii, V.V. The ichthyofauna of the reservoirs and lakes of Murmansk oblast . - In book: Fishes of Murmansk oblast, Murmansk Publishers, 1966, pp 177-194.
4. Esipov, V.K. Materials on the biology and fishery of the Novaya Zemlya char (Salvelinus alpinus L.). - Trudy Arkt. in-ta, 1935, Vol. 17, pp 2-70.
5. Kamshilov, M.M. The significance of interrelations among organisms in evolution. Moscow-Leningrad, Publishing House of the USSR Academy of Sciences, 1961, 135 p.
6. Kolyushev, A.I. Materials on the maturation and fecundity of the Imandra L. and Umbozero L, arctic chars. - Voprosy ikhtiologii, 1973, Vol. 13, No. 14, pp 633-646.

7. Mitenev, V.K., Shul'man, B.S. The parasite fauna of the fishes of the Bering Sea. Migratory fishes. In book: Ichthyofauna and the conditions of its existence in the Bering Sea. Apatity, 1986, pp 151 - 160.

8. Nesterov, V.D. Morphoecological characteristics of the migratory arctic char Salvelinus alpinus of the Kola Peninsula. - In book: Ecology and reproduction of salmon fishes in the basins of the White and Bering seas. Murmansk, 1985, pp 111 - 120.

9. Nelichik, V.A. Comparative characteristics of the fisheries utilization of the large bodies of water of Murmansk oblast. - In book: Fisheries investigations of the Verkhnetulomsk and Serebryansk reservoirs in Murmansk oblast, Murmansk, 1985, pp 153 - 167.

10. Savvaitova, K.A., Tsarev, Yu.I. Morphological characteristics of the arctic char from the bodies of water of the Kola Peninsula, morphogenesis and systematic position. Moscow, 1986, 26 p. Manuscript deposited at VINITI on May 20th, 1986, No. 3644-C.

11. Slastnikov, G.S. The age and rate of growth of the Novaya Zemlya arctic char (Salevlinus alpinus L.). - Tr. Arkt. in-ta, 1935, Vol. 17, pp 71-88.

12. L.O. The feeding of Novaya Zemlya arctic char (Salvelinus alpinus L.) fingerlings.- Tr. Arkt. in-ta, 1935, Vol. 17, pp 89-109.

13. Terekhin, Yu.V. Recommendations for the artificial rearing of the arctic char at the "Imandra" fish culture plant in Murmansk oblast, Murmansk, PINRO Publishers, 1984, 10 p. /36

14. Chernitskii, A.G. Ecologico-physiological causes of the polymorphism of Atlantic salmon spawners. - Vorprosy ikhtiologii, 1986, Vol 26, No. 3, pp 524 - 526.

15. Chernitskii, A.G., Loenko, A.A. The state of the osmoregulatory system and possible ways of differentiating various forms of the Atlantic salmon. - Voprosy ikhtiologii, 1983,,Vol, 23, No. 6, pp 974 - 983.

17. Andersen, C. The arctic char - an interesting fish for farming in North Norway. - Glott Fra Tromso Museum, 1976, No. 6, 1.

30. Pohlhausen, H. Arctic char held in net enclosures. - Fisch, Teichwirt, 1984, Vol. 35, No. 9, pp 266-268.

31. Pohlhausen, H. Consideration of high-alpine bodies of water for use in fish management. - Fisch. Teichwirt, 1985, Vol. 36, No. 5, pp 134 - 138.

32. Steiner, V. The cultivation of arctic char - Salvelinus alpinus L. - Osterreichs Fischerei, 1984, Vol. 37, No 1, pp 15-23.

ЛИТЕРАТУРА

1 БЕРГ Л.С. Рыбы пресных вод СССР и сопредельных стран. Т.I, М.-Л., Изд-во АН СССР, I948, 446 с.

2 ВЛАДИМИРСКАЯ М.И. Форель озерная, или кумжа ручьевая, в водоемах бассейна озера Имандра. - Бюл.Моск.о-ва испытателей природы, отд. биолог., I957, т.4, с.37-5I.

3 ГАЛКИН Ю.И., КОЛЮШЕВ А.И., ПОКРОВСКИЙ В.В. Ихтиофауна водохранилищ и озер Мурманской области. - В кн.: Рыбы Мурманской области. Мурманск, кн.изд-во, I966, с.I77-I94.

4 ЕСИПОВ В.К. Материалы по экологии и промыслу новоземельского гольца (Salvelinus alpinus L.) - Тр.Аркт. ин-та, I935, т.I7, с.2-70.

5 КАМШИЛОВ М.М. Значение взаимных отношений между организмами в эволюции. М.-Л., Изд-во АН СССР, I96I, I35 с.

6 КОЛЮШЕВ А.И. Материал по созреванию и плодовитости гольцов и палии озер Имандра и Умбозеро. - Вопросы ихтиологии, I973, т.I3, № I4. с.633-646.

7 МИТЕНЕВ В.К., ШУЛЬМАН Б.С. Паразитофауна рыб Баренцева моря. Проходные рыбы. - В кн.: Ихтиофауна и условия ее существования в Баренцевом море. Апатиты, I986, с.I5I-I60.

8 НЕСТЕРОВ Е.Д. Морфоэкологическая характеристика проходного гольца Salvelinus alpinus Кольского полуострова. - В кн.: Экология и воспроизводство лососевых рыб в бассейнах Белого и Баренцева морей. Мурманск, I985, с.III-I20.

9 НЕЛИЧИК В.А. Сравнительная характеристика промыслового использования крупных водоемов Мурманской области. - В кн.: Рыбохозяйственные исследования Верхнетуломского и Серебрянского водохранилища Мурманской области, Мурманск, I985, с.I53-I67.

10 САВВАЙТОВА К.А., ЦАРЕВ Ю.И. Морфологическая характеристика гольцов из водоемов Кольского полуострова, формообразование и систематическое положение. М., I986, 26 с. Рукопись деп. в ВИНИТИ 20.05.86, № 3644-В.

11 СЛАСТНИКОВ Г.С. О возрасте и темпе роста новоземельского гольца (Salvelinus alpinus L.) - Тр. Аркт.ин-та, I935, т.I7, с.7I-88.

12 РЕТОВСКИЙ Д.О. Питание мальков новоземельского гольца (Salvelinus alpinus L.). - Тр.Аркт. ин-та, I935, т.I7, с.89-I09.

13 ТЕРЕХИН Ю.В. Рекомендации по искусственному разведению гольца на рыбоводном заводе "Имандра" Мурманской области. Мурманск, изд. ПИНРО, 1984. 10 с.

14 ЧЕРНИЦКИЙ А.Г. Эколого-физиологические причины полиморфизма производителей атлантического лосося. - Вопросы ихтиологии, 1986, т.26, № 3, с.524-526.

15 ЧЕРНИЦКИЙ А.Г., ЛОЕНКО А.А. Состояние осморегуляторной системы и возможные пути дифференциации различных форм атлантического лосося. - Вопросы ихтиологии. 1983, т.23, № 6, с.974-983.

ANDREWS C.W., LEAR E. The biology of Arctic Char (Salvelinus alpinus) in Northern Labrador. - J. Fish. Res. Bd. Can., 1956, vol.13, № 6, p.843-860.

17 ANDERSEN C. Sjørøye - interessant oppdrettsfiski Nord-Norge. - Glottfratromsø Museum, 1976, № 6,1.

BRAATEN B. The situation in Norway. - In: Status and prospects on aquaculture worldwide Trondheim, 1985, p.51-60.

DEMPSON J.B., GREEN J.M. Life history of anadromous arctic charr, Salvelinus alpinus, in the Fraser river, northern Labrador. - Can. J. Zool., 1985, vol. 63, № 2, p.315-324.

FABRICIUS E., GUSTAFSON K.J. Further aquarium observations on the spawning behaviour of the charr, Salmo alpinus L. - Rep. Inst. Freshw. Res. Drottningholm, 1954, vol. 35, p.58-104.

GJEDREM T. Survival of Arctic charr in the sea during fall and winter. - Aquaculture, 1975, vol. 6, № 2, p.189-190.

GULLESTAD N. On lack of winter zones in the centre of scales from Arctic charr (Salvelinus alpinus L.). - Norweg. J. Zool., 1976, vol. 22, № 2, p.141-143.

JENSEN K.W., BERG M. Growth, mortalyty and migrations of the anadromous char, S.alpinus L., in the Vardnesa River. Northern Norway. - Rep. Inst. Freshw. Res. Drottningholm, 1971, vol.56, p.70-80.

JOHNSON L. The arctic charr, Salvelinus alpinus. - In: Charrs salmonid fishes of the genus Salvelinus. E.K.Balon (ed). Pr. W. Junk Publishers, The Hague, Netherlands, 1980, p.18-92.

MARTIN W.R. Limnological and biological observations in the region of the Ungava or Chubb Crater, Province of Quebec. - J. Fish Res. Bd. Can., 1955, vol. 12, p.487-498.

MOORE J.W. Reproductive biology of anadromous Arctic Charr, Salvelinus alpinus (L.) in the Cumberland Sound area of Baffin Island. - J. Fish. Biol., 1975, vol.7, p.143-151.

NORDENG H. On the biology of charr (Salmo alpinus L.) in Salangen North Norway. 1. Age and spawning freguency determined from scales and otoliths. - Nytt. Mag. Zool., 1961, vol.10, p.67-123.

PAPST M.H., HORKY G.E. Development of an Arctic charr (Salvelinus alpinus L.) brood stock. - Aquaculture, 1984, vol.43, N 1-3, p.323-331.

ROBERTS R.A. Preliminary observations on the ionic regulation of the Arctic charr, Salvelinus alpinus. - J. Exp. Biol., 1971, vol. 55, p.213-222.

30 ROHLHAUSEN H. Seesaiblinge in Netzgehegen. - Fisch. Teichwirt, 1984, vol.35, N 9, p.266-268.

31 ROHLHAUSEN H. Hochalpine gewässer überlegungen zu Ihrer fischereilichen Bewirtschaftung. - Fisch. Teichwirt, 1985, vol.36, N 5, p.134-138.

32 STEINER V. Die Kultivierung des Seesaiblings - Salvelinus alpinus L. - Österreichs Fischerei, 1984, vol.37, N 1, p.15-23.

WANDSVIK A., JOBLING M. Overwintering mortality of migratory Arctic charr, Salvelinus alpinus (L.) reared in salt water. - J.Fish Biol., 1982, vol.20, N 6, p.701-706.

WALLACE J.C., AASJORD D. An investigation of the consequences of egg size for the culture of Arctic charr,Salvelinus alpinus (L.). - J.Fish Biol. 1984, vol.24, N 4, p.427-435.